Renewable and Sustainable Energy Reviews 41 (2015) 685–694

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Offshore wind energy: A comparative analysis of UK, USA and India

Sandhya Kota [a,*], Stephen B. Bayne [b], Sandeep Nimmagadda [b,1]

[a] Acharya Nagarjuna University, Ongole, India
[b] Department of Electrical & Computer Engineering, Texas Tech University, Lubbock, TX 79409, USA

ARTICLE INFO

Article history:
Received 17 April 2014
Received in revised form
16 August 2014
Accepted 27 August 2014

Keywords:
Offshore
Policy
O&M
Grid integration
Cost reduction

ABSTRACT

Offshore wind is one of the most fascinating industries in the renewable energy sector and it is experiencing a remarkable growth. Offshore wind energy generation offers an opportunity in the race to decrease the dependence on fossil fuels, reduce green house emissions, increase energy security and create employment opportunities. UK has proven success in offshore wind and has been enjoying the economic benefits of offshore wind since over a decade. Offshore wind energy is an emergent renewable energy industry in the United States. The United States is coping up with the challenges and heading up fast to catch up with the industry. India is still in its infancy stage where the policy frameworks are framed by MNRE government and getting ready with the tools to enter into the offshore market. This paper researches the current situation and trend of offshore wind industries in UK and US, from aspects of policy, grid connections, operation and maintenance and cost reduction and analyses the proper direction and pathways of the industry to India. Therefore this paper highlights the scenario as to how these three countries UK, USA and India, respectively, are enabling offshore wind, to make a vital and sizeable contribution to the low carbon economy.

Contents

* Correspondence to: Nyati Environ, Mapel 101, Tingre nagar, Lane no. 5, Vishraanthwadi, Pune 15, India. Tel.: +91 7798899702.
E-mail addresses: sandhya85.kota@gmail.com (S. Kota), sandeep.nimmagadda@ttu.edu (S. Nimmagadda).
[1] Tel.: +1 8067863476.

http://dx.doi.org/10.1016/j.rser.2014.08.080
1364-0321/

1. Introduction

Offshore wind power is poised to deliver an essential contribution to a clean, robust and diversified Global energy portfolio. Capturing and using this inexhaustible resource has the potential to mitigate climate change, improve the environment, increase energy security and stimulate the global economy. In the year 2013, offshore wind power installations are on track to hit a consecutive annual record globally, where developers added 1080 MW of generating capacity in the first half of the year. Although still compared to the land based wind power which is roughly around 300,000 MW, offshore capacity is growing close to 40% a year [1]. The world annual installed offshore wind capacity in the year 1991–2013 is explained in Fig. 1.

Four key conditions needs to be in place for offshore wind developments to be successful anywhere in the world. Firstly, the Government must be ready and able to create the political and financial environment that encourages growth. Secondly, an advanced technological grid parity is essential for the turbines operating above the seas. Thirdly, operation and maintenance plays a crucial role to make offshore wind farms reliable and

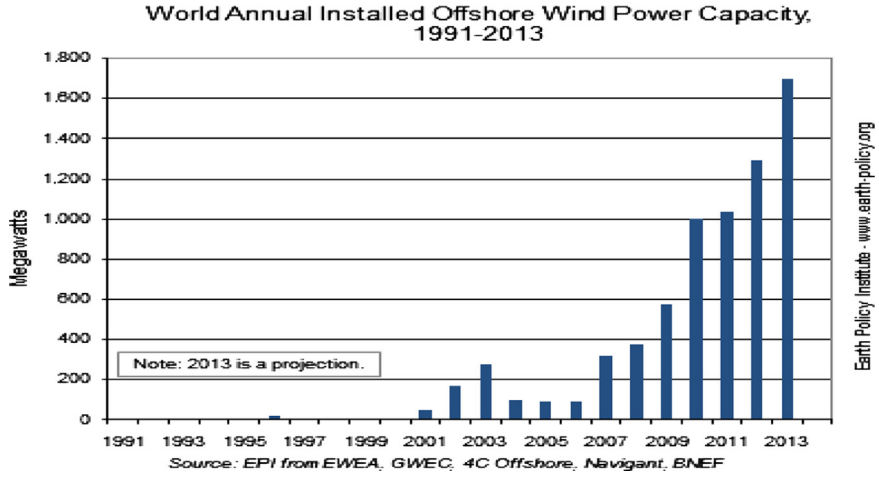

Fig. 1. World Annual Installed offshore wind capacity(1991–2013): The figure shows the world annual installed capacity from the year 1991 to 2013. Although still compared to the land based wind power which is roughly around 300,000 MW, offshore capacity is growing close to 40% a year.

economically viable. Finally, cost reduction, where maximising the economic benefit is a key priority. The main objective of this paper is to analyse the role of policy framework and grid integration aspects for offshore wind farms. Also operation and maintenance and cost reduction planning methods are focussed in this paper. Three countries have been discussed in this paper UK, USA and India, their role and contribution with regard to the above mentioned four aspects in the field of offshore wind.

UK has proven success in the field of offshore wind, which is quick to grasp both the huge opportunity that offshore wind provides energy for UK and its significant potential to contribute to the UK economy. The United States has excellent wind resources offshore and has finally joined the US offshore wind in the year June 2013, when a 20 KW floating wind turbine anchored off the coast of Maine first sent electricity to the states power grid [2]. India is the fifth largest wind energy market in the world, with over 19,500 MW capacity as of June 2013, accounting for about 65% of the total installed renewable energy capacity in the country onshore [3]. India is very soon ready to launch into the offshore sector. This paper discusses UKs success in its journey to offshore wind, lessons to be learnt by USA to overcome the challenges, and way forward for India to make offshore wind power a more prominent place in the new energy economy.

2. UK offshore wind: a success story

The UK has been the world leader in offshore wind since 2008, with as much capacity already installed as the rest of the world combined. Industry projections see a total of around 8 GW of capacity installed by 2016 and around 18 GW installed by 2020, which will provide around 20% of the UKs electricity demand annually [4,5]. The combination of the resources and energy density puts the UK in the pole position to reap the huge potential that wind offers as a generator of low carbon energy.

2.1. UK policy

2.1.1. Overview of the UK government

The UK Government has promised to meet 15% of the UKs energy demand from renewable sources by 2020, as part of the drive to decarbonise the energy sector [6]. Government policies play a significant role in promoting carbon emission reductions, decarbonisation, economic growth and energy security.

2.1.2. Renewable Obligations:(RO)and Feed In Tariffs

The Renewable Obligation (RO) and Feed In Tariffs(FITs) are part of the Governments strategy for increasing renewable electricity generation. RO is a certificate trading scheme and places a mandatory requirement on UK suppliers to source a proportion of their electricity from eligible renewable sources. This incentive proved very attractive, where the suppliers are obligated to have an increasing part of the electricity come from Renewable generators, with targets starting from 5% in 2003 rising to 10% in 2010 [7]. FIT scheme pays energy users who invest in low carbon electricity generation system for the electricity they generate and use. The unused electricity is exported back to the grid. The support for low carbon generation is provided through mechanisms such as RO and FIT, which proved very effective with the current costs of production.

2.1.3. UK Renewable Energy Roadmap

UK Renewable Energy Roadmap was published in 2011 by Department of Climate Change (DECC) which presented the framework for the delivery of renewable energy deployment in UK. [8]. The main purpose of this roadmap, is to provide analysis on the progress and changes of the year including renewable energy deployment, in each year up to 2020 along with technology cost projections. All these supplementary policies, measures and support programmes further stimulated and upgraded the development of offshore wind industry in UK.

2.1.4. Electricity Market Reform

In order to make sure that UK remains a leading destination for investment in low-carbon electricity, Electricity Market Reform (EMR) has been published. EMR offers guaranteed price support through contracts for difference, subject to the energy bill and aims to give industry the certainty it needs to enable ongoing investment in offshore wind projects. This transformed the UK electricity sector to enable low carbon generation to compete with other fossil fuel and conventional generation [9]. Most significantly, it is the UK Government which has shown the world how to roll out offshore wind.

2.2. Grid connections in UK

2.2.1. UK grid status

UK is fully utilising its offshore wind potential and ensuring security of supply, as a suitable electrical grid is fitting the purpose. The proportion of electricity fed into the grid from offshore wind turbines in UK is 8% and is projected to reach 20% by the end of the decade [10]. Building the transmission network and other infrastructure and then connecting it to the grid requires a substantial investment. It is estimated that the investment to connect the projects could be approximately up to £15 billion [11].

2.2.2. Role of OFTO

Unlike other countries, where the offshore transmission assets falls to either wind farm developer or the onshore transmission operator, UK has a separate Offshore Transmission Owner (OFTO) which takes the responsibility of the assets under long term licences. OFTO is a body operating grid connections between offshore farm and onshore network [12]. OFTO represents an investment opportunity in a precisely defined type of asset which is supported by a strong underlying regulatory regime. The government (DECC) and energy regulator Office Of Gas and Electricity markets (OFGEM) have established a competitive regulatory regime for offshore transmission. The regime was designed to ensure that offshore renewable energy projects are efficiently connected to the grid. Such strong regulatory bodies are the reasons for UKs success.

2.2.3. Reduction of grid costs

Grid infrastructure typically accounts for around 10–20% of the capital costs for construction of an offshore wind farm. Helping deliver cost effective and reliable grid connections, which will allow developers to export energy, is a crucial element in the offshore wind sector. According to UK Offshore Wind Report as on 2012, the total capacity of offshore wind schemes with connection agreements on place with National grid is 35.2 GW [13]. Several initiatives were taken to reduce the cost of grid connections for offshore wind. These include improving the OFTO process, development of a coordinated network designs and associated anticipatory investment and so on. Such initiatives gave rise to a significant degree of certainty about the future policy framework for offshore transmissions [14].

2.3. UK operation and maintenance

2.3.1. UK facilities

UK has a proven record of expertise, with dedicated O&M centres opened, host of training opportunities and companies entering the supply chain helping increase the number of qualified personnel. The maintenance cost of offshore wind installations is £250,000 per wind turbine or £79,000 per installed megawatt of capacity per year [14]. Health and safety is the key element of O&M, where UK offshore industry places a strong emphasis on health and safety and has taken up precautionary measures.

2.3.2. Market for UK

Perfect O&M policy implies maximum availability at least cost by ensuring the best possible access to offshore plant, in minimising unscheduled maintenance and carrying out scheduled maintenance [15]. Fig. 2 explains the UK offshore wind spent on operation and maintenance. UK has been efficiently trying this combination, ultimately resulting in the lowest possible cost of energy.

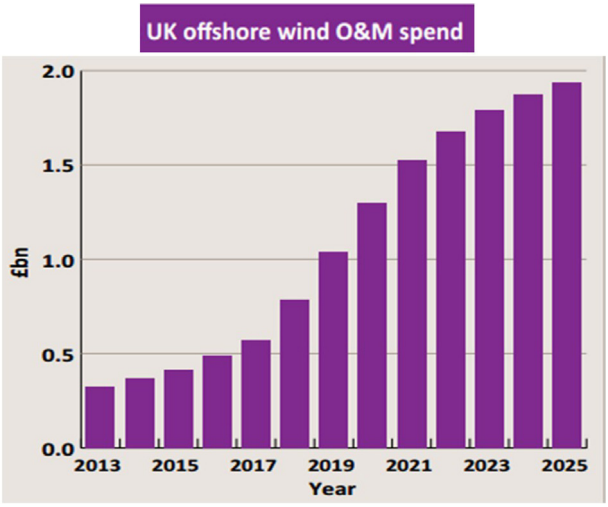

Fig. 2. UK offshore wind O&M spend: the expenditure on UK offshore wind O&M is shown along with future projection. By 2020, the offshore market in UK waters is predicted to grow by 8000 turbines. Once the installation is done the turbines have to be carefully operated and maintained, over a lifetime of next 20 years.

2.3.3. Proximity to the shore Is an advantage

More the projects move further from the shore and into deeper water, more are the challenges faced by O&M team. Therefore, proximity to the shore is always an added advantage. The O&M base in Ramsgate is close to two offshore wind projects which are London Array and Thanet [15]. This has an advantage to draw good port facilities, ability of local educational establishments to train staff and also local skill sets. In spite of the challenges, UK is rapidly growing in the offshore industry and with it a huge market for O&M services is emerging.

2.4. Cost reduction a priority

UK has an unparalleled record of deployment. But there lays a responsibility to deliver the green energy future at the lowest possible cost to the consumers. Based on Fig. 3 future costs will be critical in determining the future size of the industry in the UK. Therefore cost reduction opportunities have to be identified and quantified for the offshore wind industry.

2.4.1. Cost reduction taskforce

The UKs offshore wind programme may require £50–£100 billion to be invested in the next ten to fifteen years [16]. Significant cost reduction provides an opportunity for the UK to develop an area of competitiveness in a growing global industry. The government therefore established The Offshore Wind Cost Reduction Taskforce (CRTF) a taskforce to produce an action plan to get the levalised cost of energy (LCOE) down to £100/MWh by 2020. CRTF top priority is to bring down the costs and achieve 18 GW by 2020 [17].

The taskforce key recommendations are as follows:

1. The government should deploy the Green Investment Bank (GIB) in the offshore wind sector to facilitate and leverage the entry of new capital.
2. The industry and GIB should investigate the development of vehicles for pooling wind assets to provide risk diversity and facilitate recycling of utility capital.

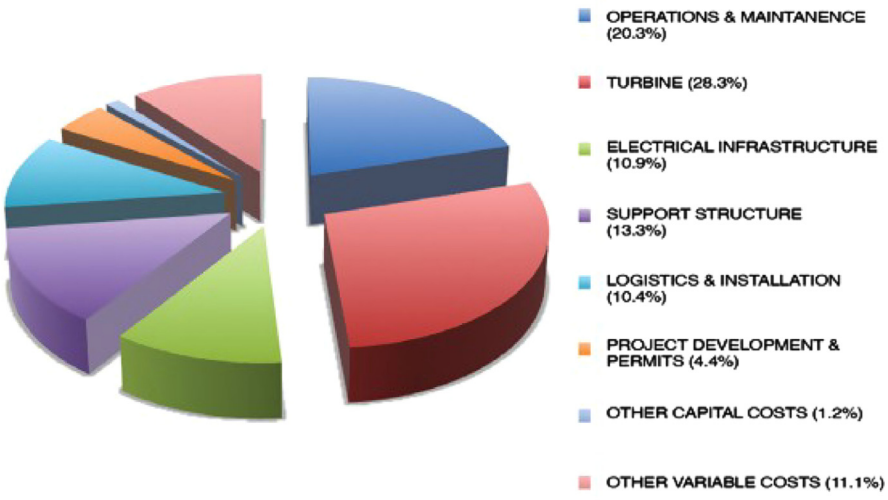

Fig. 3. Cost reduction a priority: the figure shows future costs will be critical in determining the future size of the industry in the UK. Therefore cost reduction opportunities were identified and quantified for the offshore wind industry.

3. The insurance sector should be involved to explore ways that their experience and product range can be used to mitigate risk during construction and operation.
4. The entry of long-term risk capital should be encouraged to lead the education and briefing of the finance sector.

The Cost Reduction Task Force identified the need to better educate the finance sector on true risk but there is also an urging need to educate about the cost reduction opportunities. By developing evidence on the potential for cost reduction in offshore wind, the UK industry enhanced different combinations of improvements in technology [18].

2.4.2. Key considerations for cost reduction

The key areas for cost reduction which are responsible for the UK to be the world's attractive investment environment are explained below.

- Firstly, larger turbines at low operating costs and higher reliability were introduced.
- Secondly, a greater activity was set up at the front end of the project including the early involvement of suppliers, multi-variable optimisation of wind farm layout and more extensive site surveys.
- Thirdly, exploitation of economies of scale and productivity improvements were done including greater standardisation, capturing and building on learning by doing and better procurement.
- Fourthly, there was optimisation of the current installation methods.
- Finally, mass produced support structures were introduced for use in water depths greater than 35 m. Therefore, UK is all set to achieve the 2020 target by fully utilising the opportunities that are currently being developed and introduced [19].

2.4.3. Cost reduction: gateway for UKs success

This confirms that offshore wind in UK can reduce its costs significantly down to £100 per MWh by 2020.Success in cost reduction will cement the industry's future in UK and help the country secure the position as a global expert in offshore wind. However, with an opportunity presented by the renewable sector, providing business support and assisting inward investment through offshore, UKs aim to remain at the forefront of global low carbon energy revolution is achieved [19].

3. US offshore wind: a powerful challenge

The United States has a very large offshore wind resources due to strong, consistent winds off the long US coastline. The offshore wind power in the United States is feasible to meet 20% of US electricity demand by 2030, which would require an increase capacity to over 300 GW [20]. While there are no commercial scale projects in operation till date, eleven projects representing 3.824 MW now lie in the advanced stages of development [21,22]. Fig. 4 shows the announced locations and capacities of these proposed projects.

3.1. US policy

3.1.1. US offshore incentives

The United States has created a combination of useful incentives for offshore wind sector which will contribute to the decline in emissions. Federal incentives in form of tax credits and accelerated depreciation play a vital role in offshore wind. At the federal level, the primary drivers for cost competitiveness of offshore wind energy, are the renewable Electricity Production Tax Credit(PTC) and the Business Energy Investment Tax Credit (ITC). Investors in wind projects are eligible to choose between these two incentives, and most of them opt for ITC (30% of initial capital cost) over PTC ($23/MWH for the first ten years) as it offers

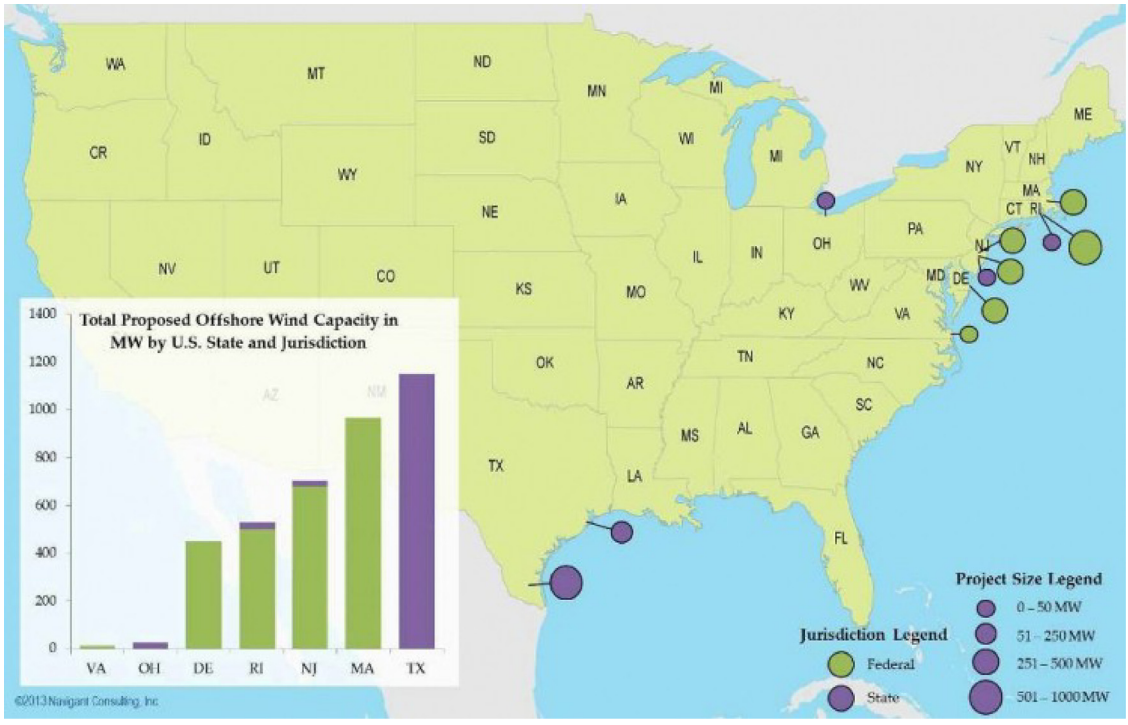

Fig. 4. Proposed offshore wind capacity in US: the figure illustrates the proposed offshore wind capacity in US.

a relatively larger support for offshore wind energy [20]. In January 2013, The American Taxpayer Relief Act of 2012 further extended the 50% first year bonus depreciation allowance for property placed in service during 2013 [21,22].

3.1.2. Challenges faced by US waters

The United States has a successful track of managing renewable energy industries on land with supportive policies, but lags behind when it comes to offshore wind industry. It is relatively a new industry and is coping up with the challenges. Chief among them is the absence of a coherent energy policy that acknowledges the global responsibility to reduce greenhouse gas emissions. The Government financial support for emerging energy industries is fragmented and inconsistent. The policy framework lacks commitment to specific targets and timelines, that drive successful overseas offshore wind markets. The main hurdles for the US offshore wind are the high capital cost requirements, regulatory issues and a backlash from local communities and most importantly the federal incentives failure to compensate for such difficulties.

3.1.3. Lessons from the UK

The policies that UK put in place are learning aspects for US as they are designed to attract investors, commercial banks and project developers. UK has fairly stable policies to promote offshore policies for about a decade and above. So far US approach has been a hit and miss policy which has been a major hurdle for flourishing the offshore wind. A country can develop a strong offshore wind industry only through a long term policy framework in favour of the offshore wind. The UKs has a consensus in favour of the offshore wind in spite of the change in governments. The United States can take the lead by ensuring revenue certainty through strategically refining the innovative Offshore Wind Renewable Energy Certificate (OREC) programmes. Another great option is to leverage the resources of commercial banks and make sufficient low cost debt available.

3.2. Grid connection in US

3.2.1. Current status of US offshore grid

Deployment of offshore wind in United States is largely dependent on the grid infrastructure. The offshore grid will have unique characteristics that warrant more in depth studies, including grid-fault and stability analysis. Another important factor in grid integration of offshore wind energy in the United States is availability of suitable transmission injection points. As wind farms grow in size, the behaviour and modelling of offshore electrical transmission systems should be analysed with respect to the grid system reliability, grid losses and grid architecture options.

3.2.2. EWITS, benchmark for necessary grid expansion

Offshore wind scenarios were analysed with a comprehensive grid integration study, which is Eastern Wind Integration Transmission Study (EWITS). Nearly 80 GW of offshore wind was studied in the highest penetration scenario. In this study, specific offshore grid distribution and transmission were identified along with the cost estimates [23]. EWITS acts as a benchmark for the identification and comparison for necessary grid expansion and interconnect options. The ongoing growth in the wind turbines installations in the United States requires the transmission system operators to tighten their grid connection rules to obtain a better control of the production, to avoid variability and also to ensure network quality.

3.2.3. Lessons from UK

Grid connection remains one of the greatest bottlenecks to offshore wind development in the United States. Grid infrastructure, investment and access are the key challenges to move forward with success. UK has succeeded in overcoming these challenges and has been the world leader in offshore wind. Some recommendations can be given based on the UK offshore experiences. They are:

- Firstly, grid reinforcements are necessary in order to facilitate the grid connection of offshore wind farms in future.
- Secondly, common offshore cables bundling several wind farms can be beneficial.
- Thirdly, grid access, energy pricing and balancing are interrelated. To increase the value of the wind energy, measures such as adapted demand control, back up generation and storage are needed.
- Finally, in wind transmission grid codes there is a trend towards active control of large wind farms within the boundaries of legal frameworks. This contributes to grid stability. Therefore to sum up many things have to be done on a technical level in order to integrate large amounts of offshore energy in the US power system.

3.3. US offshore operation and maintenance

3.3.1. O&M-priority for cost reduction

O&M represents about one fourth of the cost of energy for offshore wind. This high share results from the cost of accessing and maintaining the turbines. This is based on a number of variables such as distance from the shore, metrological ocean conditions and port location and also to enable offshore wind farm operators to select the best strategy for their site [24]. New special purpose service jack-up barges are expected to enter the market within few years, which can make an important contribution to cutting O&M expenditure. Based on the design, new jack-ups could also save on the port charges. The new generation of O&M vessel designs, tailored for the needs of the offshore wind, marks the beginning of a wave of cost cutting. This could substantially reduce the cost of energy within the next few years [25].

3.3.2. Challenges faced by offshore O&M in US

As projects move further from the shore to deeper water, there are many challenges faced by O&M. From logistics to improving scheduled maintenance, it has to be ensured that the best strategies are in place to increase reliability and reduce cost of energy [26]. The only challenge faced is that standardised, technical and commercial practises have not yet been emerged. Accepting that there are many paths offshore O&M can take, lessons from UK, sets out fundamental drivers that will shape the industry and sheds light on the scale and nature of opportunities it presents.

3.3.3. Lessons from UK

Some recommendations also can be given based on the UKs experience.

- Health and safety must be given utmost emphasis. For example to enhance health and safety most of the monitoring can be done remotely.
- Formalised guidelines and training programmes, can be given in order to build the skill of the O&M staff to internalise the safety precautions.

- Each turbine can have as 300 sensors feeding information back to an onshore base, where the technicians can fix an estimated 80% of problems by sending signals back to the turbine.
- One of the major aspect that can be learned from the UK, is that the overall design of the turbine can be done carefully in order to avoid the number of components and their functional complexities, which will could save a lot of time and money further down the line.

3.4. US offshore cost reduction pathways

3.4.1. Challenges faces by the US waters

The challenges of cost competitiveness are firstly, the high costs of the offshore turbine technology itself, secondly the lack of installation, maintenance and interconnection systems of offshore wind and thirdly the multi jurisdictional permitting and siting process for development offshore. Fig. 5 explains the cost of the offshore wind power at present and the targets in the future.

Department of Energy is pursuing a national work plan to deploy 10 GW of offshore wind capacity by 2020 and 54 GW by 2030 [27]. Development at this scale would generate investments for manufacturing and project deployment. While offshore wind presents a huge opportunity for economic progress, complex issues remain that require state, federal and state cooperation. In order to tackle the barriers of offshore wind development through focused collaboration and cooperation in an accelerated time-frame, clean energy group supported by private foundations are assisting state and federal officials and taking steps to increase investment in the field of US offshore wind industry. Some of them are listed below:

- Increase ongoing cooperation and communication on priority problem solving.
- Advance investment through power procurement cooperation through new financing mechanisms by state and federal agencies.
- Launch cooperative opportunities and identify supply chain to build industry infrastructure.
- Develop an information platform to provide access to recent data information on investment analysis.
- Use the policy mechanisms, such as Feed In Tariffs, production and investments tax credits to increase the long time demand and supply of renewable energies.

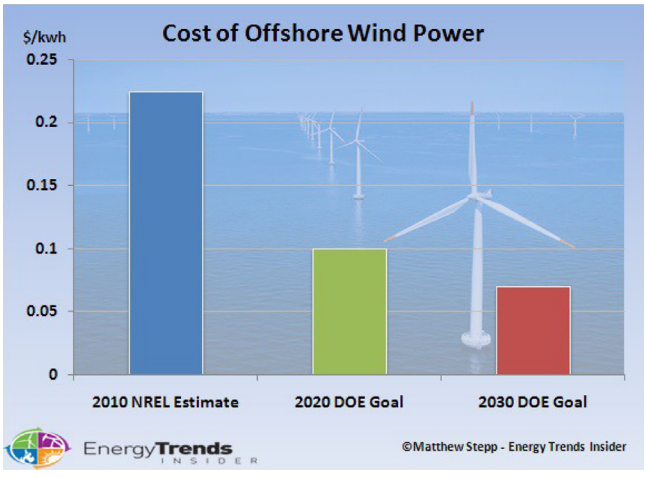

Fig. 5. Cost of offshore wind power in US: the figure explains the cost of offshore wind power and targets in US.

A modest investment in offshore wind would supply almost half of the current electricity generation on the East coast in US [27]. Considering the above points, US should craft functionally similar solutions that unleash the American offshore wind energy potential and deliver environmental and economic benefits.

3.4.2. Measures to reduce costs

Offshore Wind Initiation and Demonstration(OSWIND) is an initiative to promote and accelerate responsible commercial offshore wind development in the US in both federal and state waters. Its long term strategy will focus mainly to reduce the life cycle costs of offshore wind energy and also to expand access to most promising wind areas. This can be effectively done in the following ways:

1. By increasing system efficiency and decreasing the capital costs through the development of larger systems, fully integrated system designs and innovative components.
2. Reduction of overall costs by decreasing operational and replacement costs.
3. By reducing the project risk, the financing components of cost of offshore wind energy can be reduced [28].

3.4.3. Lessons from UK

Cost Reduction Task Force was invited to apply opportunities for savings across the finance. Some strategies can be learned from UK to reduce the costs.

- Concentration can be on risk reduction to facilitate the initial deployment of offshore wind projects in the US waters.
- New technologies can be developed that will lower the cost of energy and also sustain the growth of the industry which will make offshore wind in US very cost competitive.
- Deployment of the initial projects in the US waters can be a top priority as this will be a learning experience and highlight unforeseen issues.

The United States can also be a big part of this global success story and prosper as a result, provided all the prerequisites are correctly in place and urgent action is taken.

4. Indian offshore wind: has oceans of opportunity

India ranks 5th in the world in onshore wind energy and is sure to grow in offshore industry too at its own pace [29]. Since offshore wind industry is yet to begin in India, it can take the lessons from well experienced countries like Britain and developing countries like USA. From Fig. 6, it is clear that there are many operational wind farms where India is in its beginning stage. The preconstruction phase is typically calculated based on the best information available. Hence these guidelines can help India to move forward without leading to unfavourable financing conditions and possible error in the prediction.

4.1. Indian policy

4.1.1. Recommendations to Indian offshore wind

4.1.1.1. Establish stable and coordinated long term markets for offshore wind. MNRE and the other member states must work together to ensure that the policies for offshore wind in India are stable, long term and smooth. The coordination of policies to support the sector is essential to allow investments to be made with confidence, so that markets will not be in excessive competition with each other. In other words a stable policy

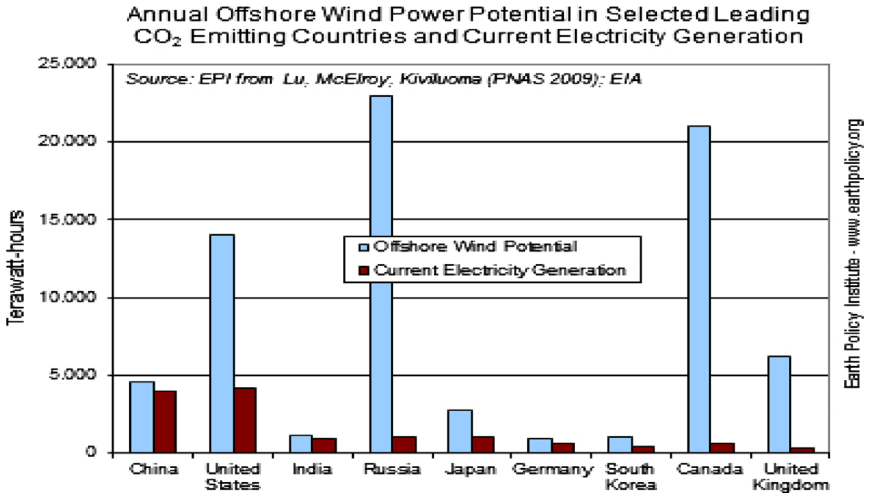

Fig. 6. Annual Offshore wind power potential: Fig. 6 explains the annual offshore wind power potential of different countries. From Fig. 6, it is clear that there are many operational wind farms where India is in its beginning stage. The preconstruction phase is typically calculated based on the best information available.

network is very much necessary to boost investor confidence without uncertainties [30].

4.1.1.2. Create stable rules and processes for transmission and grid integration. To facilitate the interconnection of future offshore wind energy facilities, it is necessary to create a predictable transmission and grid integration regulatory environment with clear allocation of responsibility. This can be achieved by monitoring the national and regional power system rulemaking regarding the implications for offshore wind energy and also by coordinating with state and local energy providers.

4.1.1.3. Simplify certification and approval criteria. The joint review of certification and approval standards by the industry, operators, certifying entities and the federal maritime agencies can optimise processes and standards. Uniform certification will simplify the situation and to a great extent help in cost reduction. It is recommended to use the experience gained by the developed countries like UK for classical approach in the offshore industry.

4.2. Grid connections

Grid connections, poses a central challenge in the use of technology in technical, economic and logical perspective. Some suggestions may be followed for grid network.

4.2.1. Develop an integrated approach between onshore and offshore network

Every development to a transmission network has an interaction with the existing network. Reinforcement onshore is very much required for the introduction of generation onshore. This will provide routes through the onshore networks to other parts of the offshore network for bulk power transfer. However, both offshore and onshore networks are symbiotic in nature, which will assist one another and minimise the overall development requirements.

4.2.2. Integrating future scenarios for offshore wind power development

Transmission network developments must be designed not only to meet the initial needs of the network but also be resilient to the future needs. However, predicting the future needs with any level of certainty is a challenge for the country. The best practise approach is to envisage a number of future scenarios which cover the plausible range of developmental changes to the network.

4.2.3. Adopt modern technologies for higher efficiency

Modern technologies like high voltage direct current transmission technology(HVDC) should be used for higher efficiency and in order to prevent high transmission losses in case of longer distances. The use of HVDC in developed countries have proved lower power loss and can convey more power per cable in the event of longer distances. Adopting smart devices which are used for controlling power flows in the network is also a good option.

4.3. Operation and maintenance

Certain operation and maintenance guidelines if followed, will provide a good starting point for the Indian offshore industry.

4.3.1. Offer rules and guidelines that cover all aspects of operation

Guidelines can be given for each phase of operation and maintenance which includes health, safety, training, management and so on. This will lead to obtain a greater knowledge on the way the wind turbine and its components behave from a reliability point of view.

4.3.2. Provide personal access solutions which give a safe and a speedy passage

The challenge for providing support during construction, operations and maintenance will be growing. Therefore its very much essential to provide personal access solutions to be safe, fast and cost effective. This can be done by deploying crew boats that transfer personnel to the site. Helicopter access should be available to access the wind plant, which will reduce the travel time to a large extent as it is not limited by wave height.

4.3.3. Provide a cost benefit analysis of innovative O&M

A growing range of propositions should be offered which include advanced transfer systems, faster vessels, more reliable wind turbine drive trains, increased redundancy in the wind farm design and so on. In order to encourage these innovative propositions early in the development of an offshore wind farm, the benefits and risks can be compared with much developed country like UK, which will allow us to focus on the key parameters.

4.4. Costs reductions

India is the most attractive place for offshore wind investment and large incentives. The chart below explains the drivers to reduce offshore wind energy costs which explains to achieve cost competitiveness and ensure increased investment in the field of offshore wind industry. To achieve this purpose certain guidelines given below can be followed.

Wind turbines	Foundation	Logistics	Grid connection
• Examples: • Wider choice of concepts • Larger wind turbines • Special design for offshore installation, operations and maintenance	• Examples: • New, industrial-scale foundation concepts • Lower material costs • Shorter installation time and lower installation costs	• Examples: • vessels • Suitable ports • Optimised processes allowing shorter installations times and better access to offshore sites	• Examples: • Foresighted planning • Building up of offshore grid infrastructure • Efficient bundling of grid connections of offshore wind farms.

Drivers for cost reduction.

4.4.1. Develop clear understanding of the current costs of offshore wind energy systems

Efforts should be made that all the costs are properly understood. A detailed life cycle cost breakdown for all components of a project should be prepared to identify and prioritise the components having largest cost reduction potential. This could help identify unknown cost and risk factors, which will define barriers to cost reduction.

4.4.2. Evaluate ownership and financing structures and associated risks

It is necessary to compare the ownership financing structures and risk assessment approaches for offshore projects. The sources of risk can be identified and a mechanism should be set up from addressing them. Then characterise the risk impacts on access to and terms of financing and insurance.

4.4.3. Develop policies with a phased incentive programme to foster early development of offshore wind energy

The goal is to have cost competitive offshore wind energy in the next decade. As initial projects are developed, the incentive programs will be needed to foster and support them. Different scenarios and options for creating incentives, government long term purchase agreements can be developed through a proactive and enabling role. Such steps will help kick start a virtuous spiral of cost reduction and efficiency allowing early development of offshore wind energy, research efforts.

5. Conclusion

The offshore wind industry has experienced rapid development over a period of time, and has a central value in our energy future. According to the global Wind Energy Council (GWEC) released in 2013, the cumulative capacity reached a total of 318,137 MW, which is an increase of nearly 200,000 MW in the past five years [31]. Many regions and businesses have successfully taken advantage of this opportunity and have grown into centres for manufacturing, construction and servicing for the offshore wind energy industry. This has generated rapid economic growth, increasing potential for exports of leading technology to other regions. In this paper, we have discussed three countries viz. UK which leads the world in both deployment and ambition for offshore wind energy, USA which is in its developing stage in offshore industry and India which is all set right to lay its footprint in the offshore energy market. This paper discusses UKs success that can be used as an experience for growing offshore industry like US where India can also obtain directions to establish a successful offshore industry.

The UK has more than double the installed offshore wind capacity of any other nation and has ambitious efforts in the future. The UKs global leadership in current deployment and strong future targets are supporting the development of offshore industry that is set to provide substantial economic benefits through the first half of the 21st century and beyond. The UKs offshore wind sector capacity has grown by 79% over the period of July 2012–June 2013, according to a report released by Renewable UK [32].As offshore wind has become a more mature technology, UK has the potential to play a very significant role in the future. UK can be a good learning experience for developing offshore industry like USA and countries like India which are yet to make a footprint in the offshore industry.

The US is steadily inclining towards installing offshore wind power, with nearly dozen projects in the works, according to a new report prepared for the Department of Energy. According to the Navigant's Report, three of the projects have targeted completion date of 2015 [21,22]. A new initiative should be focussed on optimising wind power generation in turbines and at power plants through improved wind forecasting and modelling. The paper has given recommendations to overcome the challenges based on the experiences of the developed country like UK.

- Developing long term policy framework in favour of offshore wind.
- Grid network can be strengthened to accommodate in a cost effective manner.
- Optimising the installation,operation and maintenance of offshore wind.
- Modelling of wind and wave impacts on offshore wind facilities.
- Lowering the cost of foundations and systems.
- Assessing port requirements and demand for vessels.

India has a significant offshore wind power potential blessed with a coastline of about 7600 km. An indicated potential of 1 GW each at Kanyakumari and North Rameshwaram are suggested by the Scottish Development International study done in January 2012 [33]. Therefore, this is a clear indication that there is a tremendous opportunity for the development of major offshore industry with associated added value for the economy and potential in India.

Some recommendations for the Indian Offshore industry to flourish in future are as follows. Firstly, investments in infrastructure, facilitating effective stakeholder management and stable policy drivers can facilitate development in the offshore industry in India. Secondly, National and regional governments can play a key role in this respect through a proactive and enabling role. Thirdly, instructive examples can be realized from experienced offshore wind projects and new hubs that are emerging for manufacturing, technology and construction. Fourthly, it is

essential that all the parties in the industry, policy and administration should be actively involved in order to exploit the presented cost reduction potentials of offshore wind power atleast over the next ten years. Minimisation of risk also provides significant reduction potentials. Such enabling steps will help kick-start a virtuous spiral of cost reduction potential along further growth of the offshore wind energy market.

Lessons learned from UK can provide a vital experience for USA and India, which is essential to ensure that the offshore wind industry is continuing on its successful path. However, it is very well understood that there is much scope for countries which are in its initial stages of development in offshore industry like US and countries which are yet to kick-start in offshore industry like India. It is clear that strong growth in offshore wind deployment is promised, to fulfil the industry of strategic global importance, the one that helps us to secure clean energy future.

References

[1] Record year for offshore wind. 2013. Available from: ⟨http://www.earth-policy.org/plan_b_updates/2013/update117⟩.
[2] Offshore wind market and economic analysis. Available from: ⟨http://www1.eere.energy.gov/wind/pdfs/offshore_wind_market_and_economic_analysis_10_2013.pdf⟩.
[3] About Indian offshore wind installed capacity. Available from: **india**npower-sector.com/home/tag/off-shore/.
[4] New offshore wind capacity. Available from: ⟨http://www.renewableuk.com/en/renewable-energy/wind-energy/offshore-wind/⟩.
[5] UK installed capacity, Internet. Available from: ⟨https://www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies/supporting-pages/offshore-wind⟩.
[6] UK government target. Available from: ⟨https://www.gov.uk/government/…/2167-uk-renewable-energy-roadmap⟩.
[7] RO Certificate – how this incentive was useful. Accenture: changing the scale of offshore wind. Available from: ⟨www.accenture.com/us-en/…/insight-changing-scale-offshore-wind.aspx⟩.
[8] UK renewable energy roadmap: department of energy and climate change. Available from: ⟨https://www.gov.uk/…data/…/2167-uk-renewable-energy-roadmap.pdf⟩.
[9] Offshore wind energy. A UK success story. Available from: ⟨www.ukti.gov.uk/download/file/310240.html⟩.
[10] UK future energy scenarios: national grid. Available from: ⟨www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=24676⟩.
[11] Investing in Britain's future, report. June 2013. Available from: ⟨https://www.gov.uk/government/…/PU1524_IUK_new_template.pdf⟩.
[12] Examining the key credit features of UK offshore transmission owner projects. Mike Wilkins. Available from: ⟨http://www.infrastructurereviews.com/2013/02/11/examining-the-key-credit-features-of-u-k-offshore-transmission-owner-projects/⟩.
[13] UK Offshore wind report 2012, Technology roadmap. Wind energy. 2013 Edition. Available from: ⟨www.iea.org/publications/freepublications/…/Wind_2013_Roadmap.pdf⟩.
[14] Future policy framework for offshore transmission, great expectations: the costs of offshore wind in UK waters. Available from: ⟨www.ukerc.ac.uk/support/tiki-download_file.php?fileId=1164⟩.
[15] A guide to UK offshore Operation and maintenance. Available from: ⟨http://www.scottishenterprise.com/~/media/SE_2013/Renewables/Guide_to_offshore_wind_report_Interactive_Jan%202014.pdf⟩.
[16] Investing in Britains future, June 2013. Available from: ⟨https://www.gov.uk/government/…/PU1524_IUK_new_template.pdf⟩.
[17] Offshore cost reduction taskforce report. June 2012. Available from: ⟨https://www.gov.uk/…/policy…/offshore-wind-cost-reduction-task-force⟩.
[18] Costs considerations, UK offshore wind report. The crown estate. Available from: ⟨www.thecrownestate.co.uk/…/offshore-wind-operational-report-2013⟩.
[19] Renewable energy technologies. Cost analysis series. Available from: ⟨www.irena.org/…/RE_Technologies_Cost_Analysis-WIND_POWER.pdf⟩.
[20] 20% Wind energy by 2030. Increasing wind energys contribution to US electrical supply. Available from: ⟨http://www.nrel.gov/docs/fy08osti/41869.pdf⟩.
[21] Offshore wind market and economic analysis, Navigant, US Department of Energy. Available from: ⟨http://www.navigant.com/insights/library/energy/2013/offshore-wind-market-and-economic-analysis/⟩.
[22] American tax payer relief act of 2012-KPMG. Available from: ⟨www.kpmg.com/US/…/taxnewsflash/…/taxpayer-relief-act-booklet⟩.
[23] NREL: Wind Research-Grid Integration Of Wind Turbines. Available from: ⟨www.nrel.gov/wind/offshore_grid_integration.html⟩.
[24] Wind Energy Operation and Maintenance Summit. Available from: ⟨www.windenergyupdate.com/operations-maintenance-usa/⟩.
[25] Installation, operation and maintenance strategies to reduce: NREL. Available from: ⟨www.nrel.gov/docs/fy13osti/57403.pdf⟩.
[26] Offshore O&M forum: windpower monthly. Available from: ⟨http://www.windpowermonthly.com/event/11695/offshore-om-forum⟩.
[27] Offshore wind in US by 2020 and 2030. Available from: ⟨http://www.cesa.org/projects/accelerating-offshore-wind-owap/⟩.
[28] A National offshore wind energy strategy: creating offshore wind in the US. Available from: ⟨wind.energy.gov/pdfs/national_offshore_wind_strategy.pdf⟩.
[29] Policies to accelerate the growth of offshore wind renewable and sustainable energy reviews. 2013; vol. 24, issue C: pp. 473–482.
[30] MNRE government draft on Indian offshore wind energy. Available from: ⟨www.indiaenvironmentportal.org.in/…/draft-national-policy-for-offshore⟩.
[31] Global wind energy. 2013. Available from: ⟨www.gwec.net/global-figures/wind-energy-global-status/⟩.
[32] UK wind capacity grows by 80% in a year. Available from: ⟨http://cleantechnica.com/2013/11/11/uk-offshore-wind-capacity-grows-80-year/⟩.
[33] Significant wind energy potential in India. Available from: ⟨http://mnre.gov.in/file-manager/UserFiles/presentations-offshore-wind-14082013/JS-MNRE.pdf⟩.